neighborhood into Shepherd Canyon. Shephard Creek was put into a culvert as part of the railroad development in 1909. The train stopped operating in March 1957. The 1943 topographic map shows extensive road construction in the upper watershed. This development followed the construction of the Leimert Bridge across Dimond Canyon in 1926. Figures 16 and 17 depict the bridge construction and accompanying road and housing development in the Oakmore area.

Figure 14 is the 1959 topo map of the Sausal watershed. Highway 13 and Interstates 580 and 880 are built and most of the watershed is urban. Most of the areas depicted in green in the upper watershed have since been developed. Large sections of Sausal Creek and its tributaries have been culverted and their watersheds covered with urban development (Figure 18). However, land was set aside for parks in a number of locations.

IV. NATURAL RESOURCES

GEOLOGY

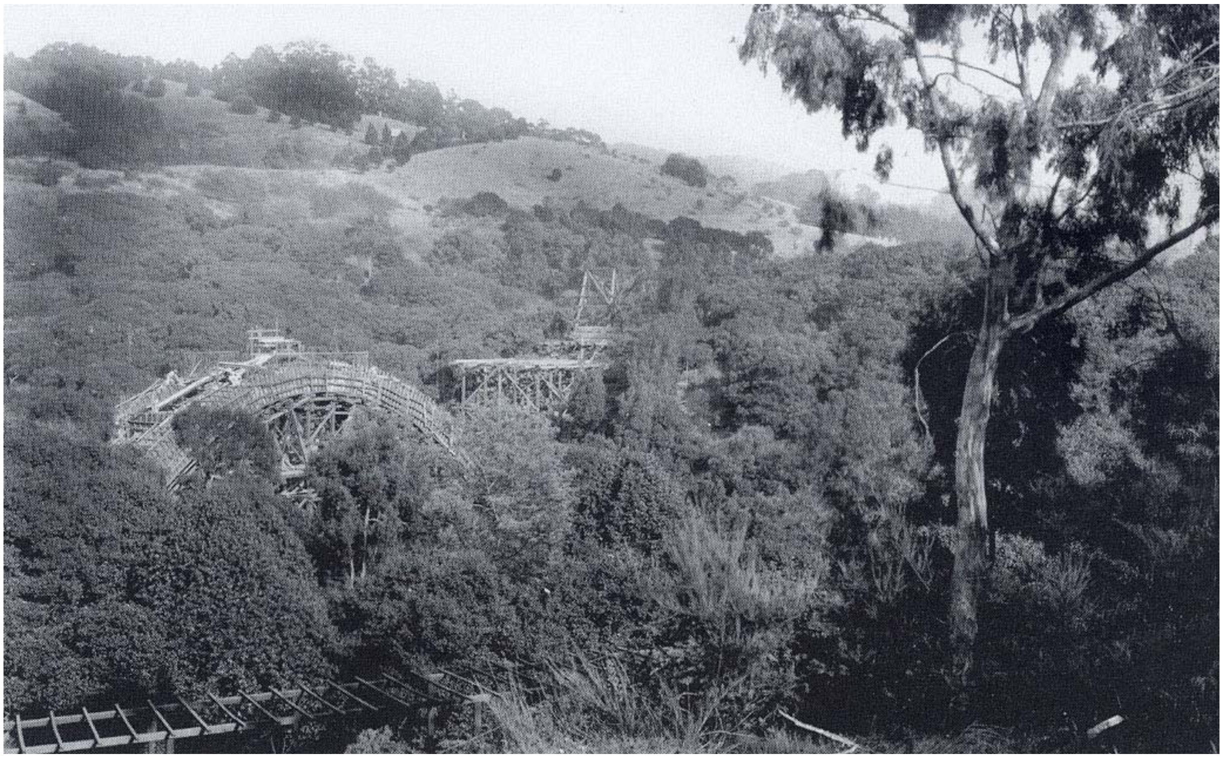
Sausal Creek is located along the eastern periphery of the San Francisco Bay (Figure 19). The steep hills on both sides of the bay were formed primarily through tectonic processes. The Pacific Plate is diving beneath and pushing up the North American Plate, crumpling the edge of the continent into the Coastal Range. The San Andreas Fault zone on the San Francisco side of the bay is one of a series of faults which dissect the Bay Area. The faults are areas of earth movement along the continental plates.

Sausal Creek watershed reflects this regional geology with very steep hills in its upper watershed. These hills are made up of a variety of rock types. The Hayward Fault is a major geologic feature which created a valley where Highway 13 is located. Downstream of the Hayward Fault on the flatter lands, Sausal Creek spreads out, creating an alluvial fan and depositing material eroded from the highly sheared rock in the fault zone and the steep upper drainage.

Figure 20 depicts the geologic features of the watershed. Table 2 describes the characteristics of each rock type. Great Valley Complex and Franciscan Complex are the primary geologic formations in the watershed. Franciscan Complex is an ancient sea floor dating from 150-200 million years ago, that has been uplifted through the movement of continental plates. Great Valley Complex is also composed of sedimentary rock and was deposited in a shallow inland sea 70-100 million years ago. Franciscan Complex is the basement rock for much of the San Francisco Bay area. As the Pacific Plate subducted or moved beneath the North American Plate, the Franciscan Complex was crumpled and uplifted into the coastal mountains. Although deposited on top of the Franciscan Complex, the Great Valley Complex rock layers often shifted from their original positions through the process of faulting and uplift.

Surface deposits are also found, including mudstones in the uppermost end of the watershed, and extensive alluvial fan deposits in the lower half of the watershed. These alluvial deposits are formed as the steep hilly area of the drainage erodes, and cobble, sand, and gravel deposit over the flatlands of the lower drainage.

Schumm, Mosley and Weaver (1987) note that
“An alluvial fan is an accumulation of sediment that has been deposited where a debris-laden stream emerges from the confined valley of an upland area onto the piedmont, where it is free to spread laterally and deposit its load. The ideal form of an alluvial fan is semicircular in plan. Because of their



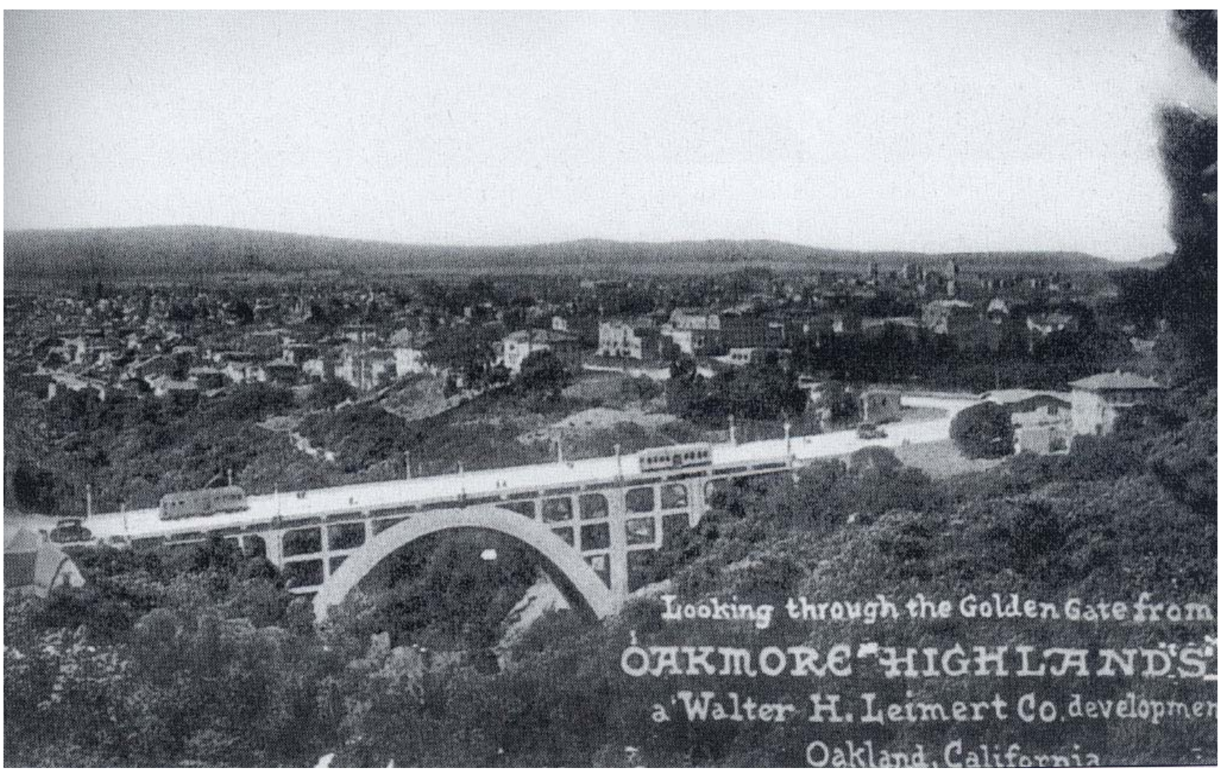


Figure 16: Construction of the Leimert Bridge in 1926 opened up large areas of the upper Sausal Creek watershed to residential development

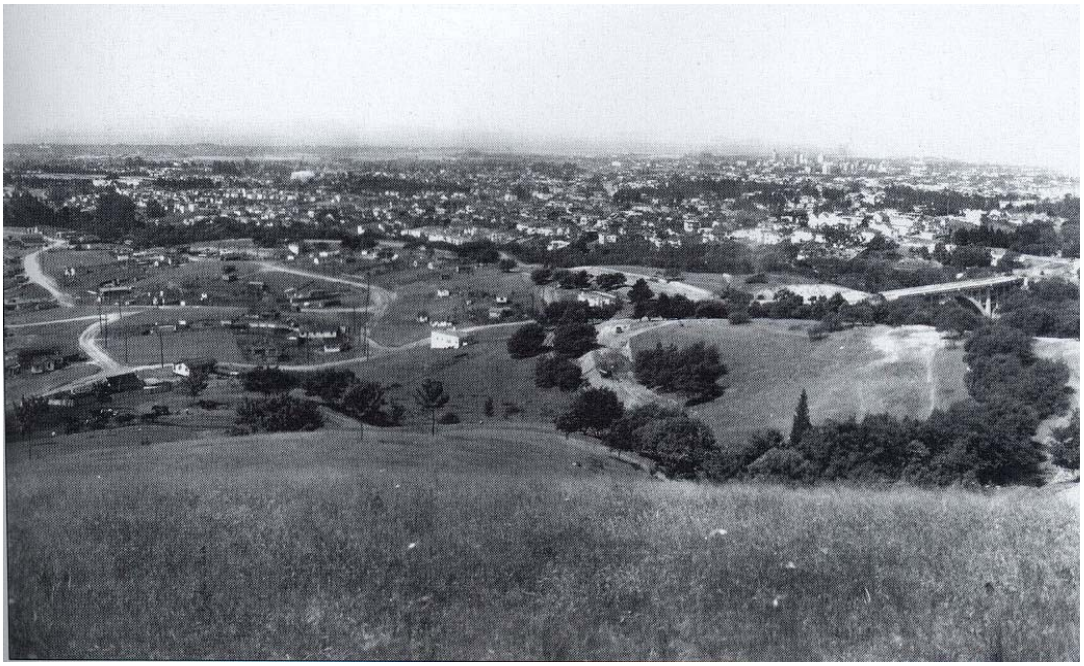


Figure 17: Top: Oakmore area in 1926 prior to the construction of large areas of housing. Bottom: Aerial photograph showing the construction of housing in the Oakmore area in 1935.

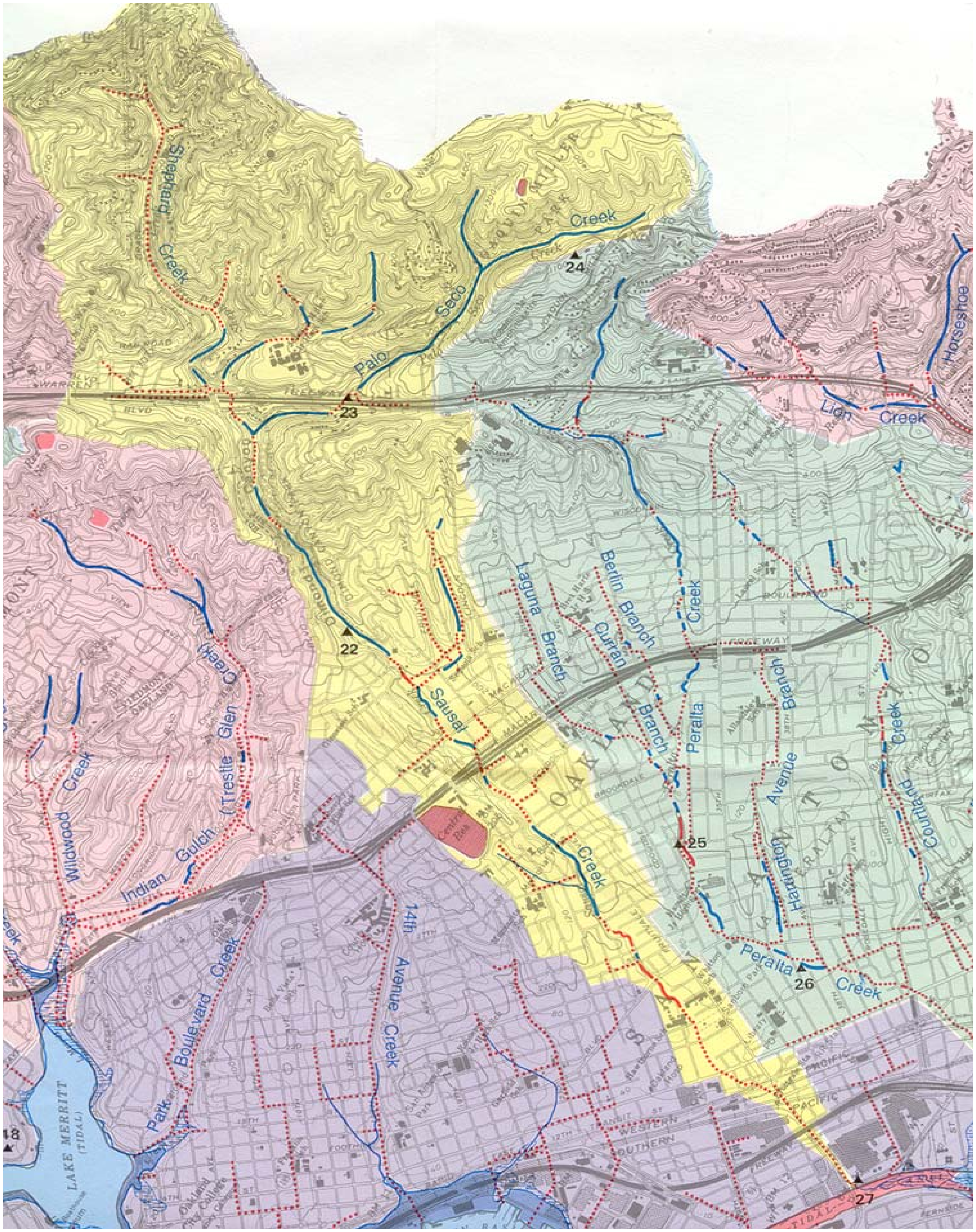


Figure 18: Oakland Museum map of creek channels in the Sausal Creek watershed, Blue indicates natural and the historic location of the channel. Red dots indicate culverted reaches and red lines indicate channelized reaches.

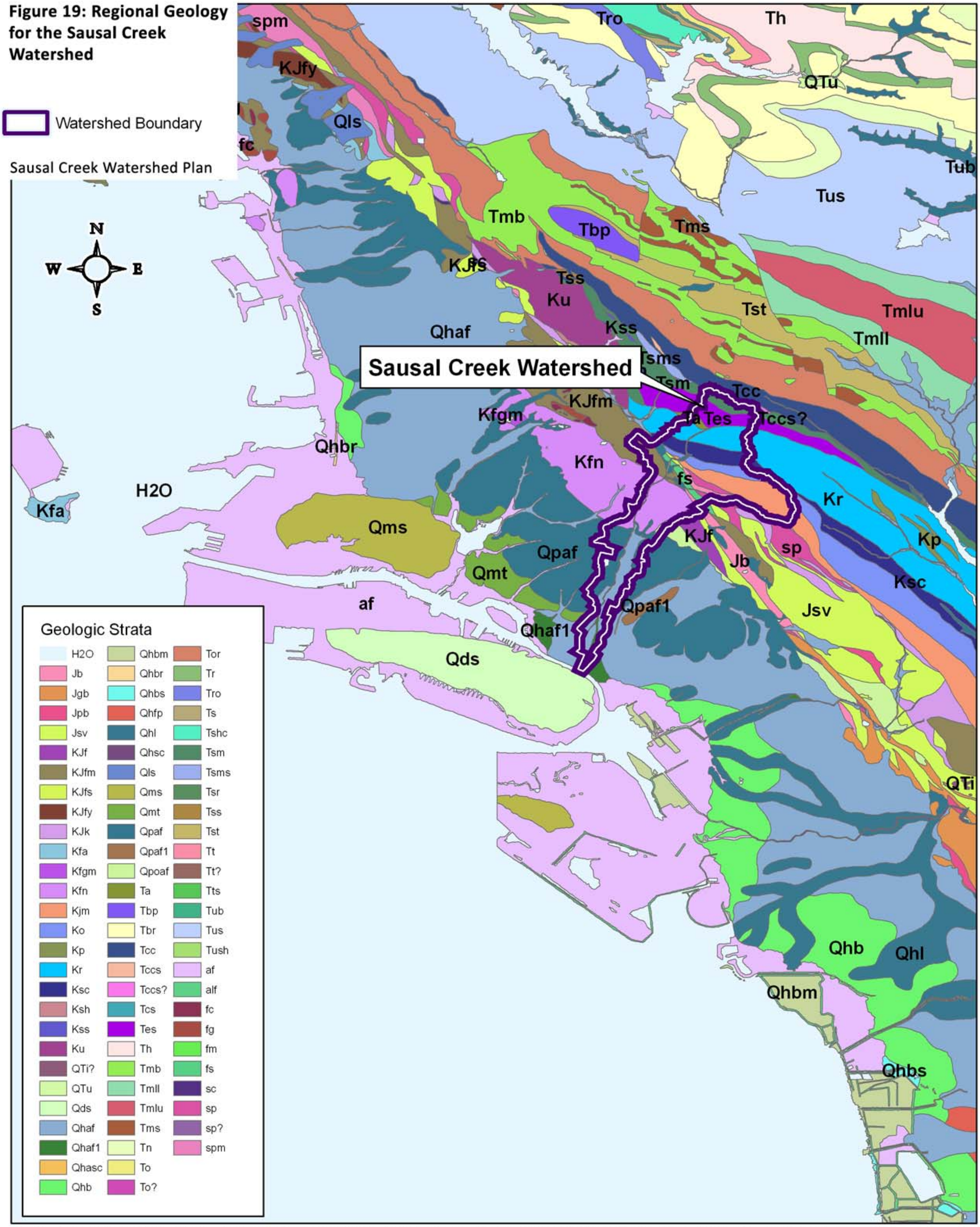
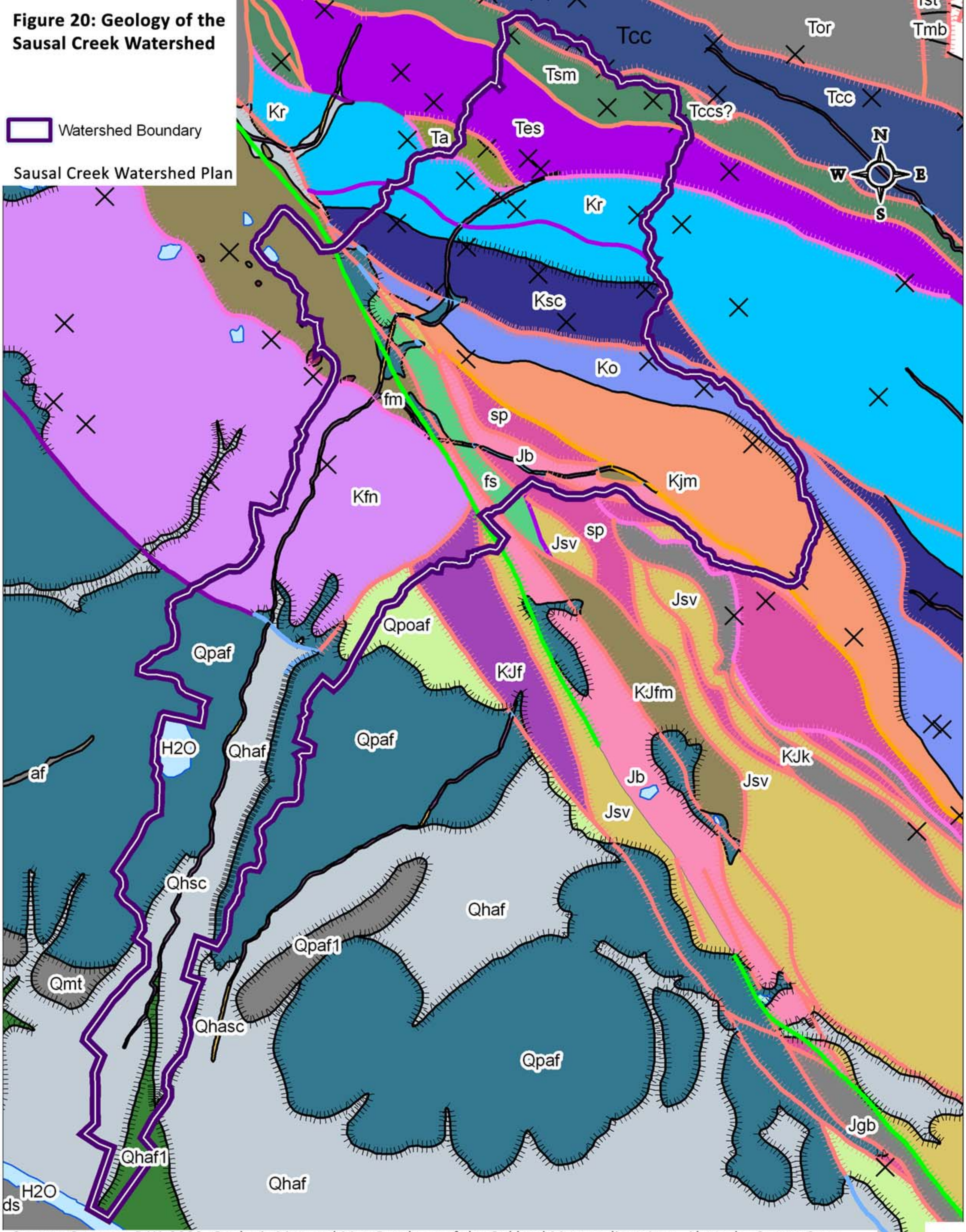


Figure 19: Regional Geology for the Sausal Creek Watershed

Source: Graymer, R.W. 2000. Geologic Map and Map Database of the Oakland Metropolitan Area, Alameda, Contra Costa, and San Francisco Counties, California. Pamphlet to accompany MISCELLANEOUS FIELD STUDIES MF-2342 Version 1.0. USGS.

Figure 20: Geology of the Sausal Creek Watershed



Source: Graymer, R.W. 2000. Geologic Map and Map Database of the Oakland Metropolitan Area, Alameda, Contra Costa, and San Francisco Counties, California. Pamphlet to accompany MISCELLANEOUS FIELD STUDIES MF-2342 Version 1.0. USGS.

excellent exposure and ease of investigation, alluvial fans in arid and semiarid areas have received the greatest attention in recent scientific literature. However, fans are also common features of more humid regions ....”

As Figure 20 shows, there are numerous faults crossing through the Sausal Creek watershed. The Hayward Fault is located approximately where Highway 13 is located. The Hayward Fault is a strike-slip fault like the San Andreas Fault. The land on the west of this type of fault moves north, while the land on the east side moves south. Figure 20 shows that there are many different rock types within the Hayward Fault indicative of the shearing of rock and north/south movement along this fault. Other faults are also indicated along a northwest/southeast axis in the upper watershed, a common pattern in California’s coastal ranges. Palo Seco Creek and the upstream reaches of Shephard Creek and flow in a southeast to northwest direction due to the effects of earth movements from faulting

The rock types in the Sausal Creek watershed affect plant species distribution, groundwater movement, and erosion potential. For example, along the contact between Oakland Conglomerate (Ko) and Joaquin Miller Formation (Kjm) there are numerous springs and wetlands. “This contact is very near Skyline Boulevard through Joaquin Miller Park, and is the source of the wetland near Sequoia Arena, and also the source for the small tributaries to Cinderella and Palo Seco Creeks. Similarly, a contact between the Oakland Conglomerate and Shephard Creek Formation (Ksc) in Beaconsfield Canyon produces riparian plants 100 feet above the creek. At the contact line, a stand of mesic coastal scrub immediately gives way to coyote brush (FOSC 2009).” Immediately following the 1989 Loma Prieta earthquake, surface water began flowing in several creeks in the Palo Seco tributary drainage. These creeks had been dry before the earthquake. Figure 21 shows the landslide hazard rating for lands in the Sausal Creek watershed and nearby region.

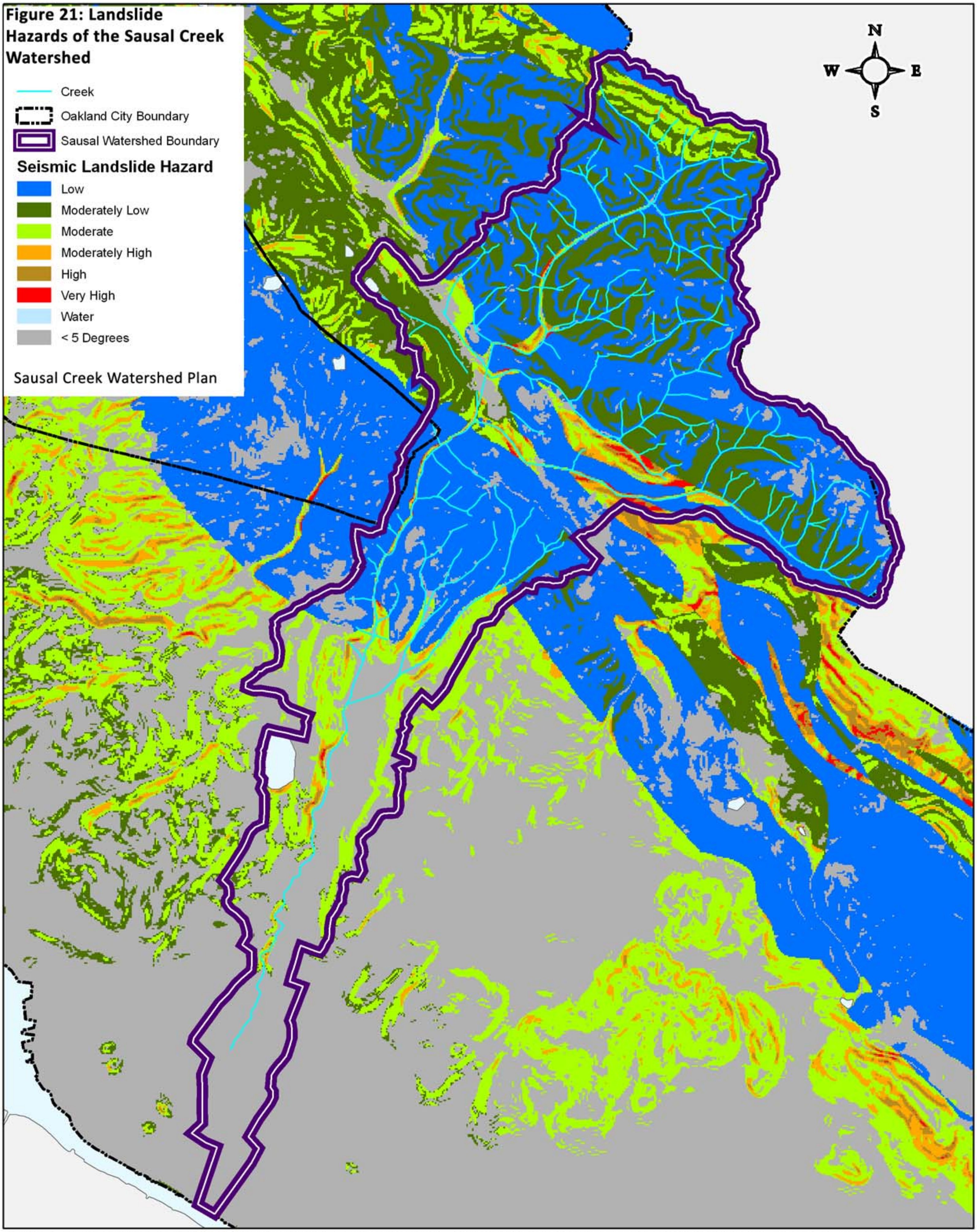
Table 2: Geology of Sausal Creek Watershed

Abbreviation	Name	Geologic Era	Description
Surficial Deposits			
Qhaf1	Younger alluvial fan deposits	Holocene (10,000 years before present)	Brown, poorly-sorted, dense, sandy or gravelly clay. Small fans at mountain fronts have a probable debris flow origin.
Qhaf	Alluvial fan and fluvial deposits	Holocene (10,000 years before present)	Alluvial fan deposits are brown or tan, medium dense to dense, gravelly sand or sandy gravel that generally grades upward to sandy or silty clay. Near the distal fan edges, the fluvial deposits are typically brown, never reddish, medium dense sand that fines upward to sandy or silty clay. The best developed Holocene alluvial fans are on the San Francisco Bay plain. All other alluvial fans and fluvial deposits are confined to narrow valley floors.
Qpaf	Alluvial fan and fluvial deposits	Pleistocene (2.5 million to 12,000 years before present)	Brown, dense, gravely and clayey sand or clayey gravel that fines upward to sandy clay. These deposits display various sorting and are located along most stream channels in the county. All Qpaf deposits can be related to modern stream courses. They are distinguished from younger alluvial fans and fluvial deposits by higher topographic position, greater degree of dissection, and stronger soil profile development. They are less permeable than Holocene deposits and locally contain fresh water mollusks and extinct late Pleistocene vertebrate fossils. They are overlain by Holocene deposits on lower parts of the alluvial plain and incised by channels that are partly filled with Holocene alluvium on higher parts of the alluvial plain. Maximum thickness is

Abbreviation	Name	Geologic Era	Description
			unknown but at least 50m.
Qpoaf	Older alluvial fan deposits	Pleistocene (2.5 million to 12,000 years before present)	Brown dense gravely and clayey sand or clayey gravel that fines upward to sandy clay. These deposits display various sorting qualities. All Qpoaf deposits can be related to modern stream courses. They are distinguished from younger alluvial fans and fluvial deposits by higher topographic position, greater degree of dissection, and stronger profile development. They are less permeable than younger deposits, and locally contain freshwater mollusks and extinct Pleistocene vertebrate fossils.
Tsm	Un-named glauconitic mudstone	Miocene/ Oligocene (35-5 million years before present)	Brown mudstone is interbedded with sandy mudstone containing prominent glauconite grains. Both rock types locally contain phosphate nodules up to one centimeter in diameter. The unit is bounded below and above by faults. It includes interbedded sandstone.
Ta	Un-named glauconitic sandstone	Paleocene (65-55 million years before present	Coarse-grained, green, glauconite-rich, lithic sandstone with well-preserved coral fossils. Locally interbedded with gray mudstone and hard, fine-grained, mica-bearing quartz sandstone. Outcrop of this unit is restricted to a small, fault-bounded area in the Oakland hills.
Tes	Un-named mudstone	Eocene (55-30 million years before present)	Green and maroon, foraminifer-rich mudstone, locally interbedded with hard, distinctly bedded, mica-bearing, quartz sandstone. This unit is bounded above and below by faults.
Great Valley Complex			
Kr	Redwood Canyon Formation	Late Cretaceous (100-70 million years before present)	Siliceous shale with interbedded sandstone and siltstone. This unit also includes maroon, concretionary shale at base. This formation was originally considered to be Paleocene, but it contains foraminifers and radiolarians of Campanian age in its type area and throughout its outcrop extent.
Kjm	Joaquin Miller Formation	Late Cretaceous (100-70 million years before present)	Thinly bedded shale with minor sandstone. The shale grades into thinly bedded, fine-grained sandstone near the top of the formation. The contact with the overlying Oakland Sandstone is gradational.
Jsv	Keratophyre and quartz keratophyre	Late Jurassic (150 million years before present)	Highly altered intermediate and silicic volcanic and hypabyssal rocks. Feldspars are almost all replaced by albite. In some places, closely associated with or possibly intruded into basalt. These rocks are probably the altered remnants of a volcanic arc deposited on ophiolite during the Jurassic Period.
Ksc	Shephard Creek Formation	Late Cretaceous (100-70 million years before present)	Distinctly bedded mudstone and shale, mica-rich siltstone, and thin beds of fine-grained, mica-rich wacke. This formation is conformably overlain by the Redwood Canyon Formation.
Jb	Coast Range ophiolite-massive basalt and diabase	Jurassic (200 million years before present)	
sp	Coast Range	Jurassic	Mainly sheared serpentinite, but also includes massive serpentinized

Abbreviation	Name	Geologic Era	Description
	ophiolite-Serpentinite	(200 million years before present)	harzburgite. In places, pervasively altered to silica carbonate rock.
Ko	Oakland Conglomerate	Late Cretaceous (100-70 million years before present)	Massive, medium- to coarse-grained, biotite and quartz-rich wacke and prominent interbedded lenses of pebble to cobble conglomerate. Conglomerate clasts are distinguished by a large amount of silicic volcanic detritus, including quartz porphyry rhyolite. Conglomerate composes as much as fifty percent of the unit in the Oakland hills, but it becomes a progressively smaller portion of the unit to the south. In areas of little conglomerate, this unit is distinguished from other Great Valley complex sandstones by its stratigraphic position, the presence of minor conglomerate, and its massive character. Includes, mapped locally: conglomerate and siltstone.
Franciscan Complex			
KJfm	Franciscan complex mélange	Cretaceous/Late Jurassic (150-100 million years before present)	Sheared black argillite, graywacke, and minor green tuff, containing blocks and lenses of graywacke and meta-graywacke (fs), chert (fc), shale, metachert, serpentinite (sp), greenstone (fg), amphibolite, tuff, eclogite, quartz schist, greenschist, basalt, marble, conglomerate, and glaucophane schist (fm). Blocks range in size from pebbles to several hundred meters in length.
KJfs	Franciscan complex sandstone, undivided	Late Cretaceous to Late Jurassic (150-100 million years before present)	Graywacke and meta-graywacke not assigned to any terrane.
Kfn	Sandstone of the Novato Quarry terrane	Late Cretaceous (100-70 million years before present)	Distinctly bedded to massive, fine- to coarse-grained, mica-bearing, lithic wacke. Where distinctly bedded, sandstone beds are about 1 m thick, and siltstone interbeds are a few centimeters thick. Sedimentary structures are well preserved. At the type area in Marin County, fossils of Campanian age have been discovered, but none have yet been collected in Alameda County. In north Oakland, the sandstone is associated with a 1-km-diameter body of fine-grained quartz diorite.
KJf	Undivided Franciscan complex	Cretaceous and Jurassic (200-70 million years before present)	More or less sheared and metamorphosed graywacke, shale, mafic volcanic rock, chert, ultramafic rock, limestone, and conglomerate. Highly sheared sandstone and shale forms the matrix of a mélange containing blocks of many rock types, including sandstone, chert, greenstone, blueschist, serpentinite, eclogite, and limestone.

Compiled from Geologic Map and Map Database of the Oakland Metropolitan Area, Alameda, Contra Costa, and San Francisco Counties, CA. by R.W. Grayner. 2000. Miscellaneous Field Studies MF-2342, USGS



Source: Richard Pike, Russell Graymer, Sebastian Roberts 2001. Map and map database of susceptibility to slope failure by sliding and earthflow in the Oakland Area, MF-2385, California, US Geological Survey, 2001.

SOILS

Soil types in the Sausal Creek watershed are depicted in Figure 22. Table 3 lists the characteristics of each soil type. The slope class of each soil type is also listed.

Soil types vary by the composition of clay, loam, sand, gravel, or rock; as well as their depth, slope, permeability, and erosion potential. These features of each soil type affect the rate of infiltration of rainwater, the amount of groundwater stored, and the type of vegetation (forest, shrub, grassland) associated with the soil type and able to protect the soil from erosion.

The soil types of the upper watershed have a high to very high erosion rating. Urbanization of these areas has created erosion problems by producing higher volumes of stormwater running off roofs, roads, and paved areas into steep natural ephemeral creek channels and onto highly erodible slopes. Ephemeral creeks only carry water immediately after a rainstorm. These steep channels, if not covered in dense vegetation, can rapidly erode when urban development increases runoff volumes. In both Shepherd Canyon and Cobbledick Creek sub-basins, housing and roads are built next to and over numerous ephemeral creeks.

Table 3: Soil Types of Sausal Creek Watershed

Soil Type Number	Name	Characteristics		
		Permeability	**Erosion Hazard Rating**	**Description**
126	Maymen loam, 30-75% slopes	High to very high runoff; moderate to moderately rapid permeability	High to very high	The Maymen series consists of shallow, somewhat excessively drained soils that formed in material weathered from sandstone, shale, and conglomerate. Maymen soils are on mountains and have slopes of 5 to 100 percent.
127	Maymen-Los Gatos complex, 30-75% slopes	Rapid to very rapid runoff; moderate permeability	High to very high	The Los Gatos series is a member of the fine-loamy, mixed, mesic family of Typic Argixerolls. Typically, Los Gatos soils have brown, light clay loam, granular, slightly acid A1 horizons, brown and yellowish red, slightly and medium acid clay loam and gravelly clay loam Bt horizons over sandstone bedrock at a depth of 36 inches.
129	Millsholm silt loam, 50-75% slopes	Low to very High runoff; moderate permeability	Very high	The Millsholm series consists of shallow, well drained soils that formed in material weathered from sandstone, mudstone and shale. Millsholm soils are on hills and mountains and have slopes of 50 to 75 percent.
130	Montara-Rock outcrop complex, 30-75% slopes	Medium and high runoff; moderately	High to very high	The Montara series consists of shallow well drained soils that formed in material weathered from

Table 3: Soil Types of Sausal Creek Watershed

Soil Type Number	Name	Characteristics		
		Permeability	**Erosion Hazard Rating**	**Description**
		slow permeability		serpentinitic rocks. Montara soils are on uplands and ridge tops and have slopes of 5 to 75 percent. Seep areas adjacent to rock outcrops may persist for several months after the end of the rainy season.
146	Urban land			
148	Urban land-Clear Lake complex	Negligible to high runoff and low to very low permeability	None to slight	The Clear Lake series consists of very deep, poorly drained soils that formed in fine textured alluvium derived from sandstone and shale. Clear Lake soils are in basins and in swales of drainageways. Slopes are 0 to 2 percent. The water table is at depths of 4 to 10 feet in the late summer and in some areas is very near the surface during wet months of winter.
150	Urban land-Tierra complex, 2-5% slopes	Slow to rapid runoff; very low permeability	Slight	The Tierra series consists of deep, moderately well drained soils that formed in alluvial materials from sedimentary rocks. Tierra soils are on dissected terraces and low hills and have slopes of 2 to 50 percent.
151	Urban land-Tierra complex, 5-15% slopes		Moderate	
152	Urban land-Tierra complex, 15-30% slopes		Moderate to high	
158	Xerorthents-Los Osos complex, 30-50% slopes	Moderate permeability; rapid to very rapid runoff	High	Xerorthents consist of soil material resulting from cutting or filling for urban development. The Los Osos series consists of moderately deep, well drained soils that formed in material weathered from sandstone and shale. Los Osos soils are on uplands and have slopes of 5 to 75 percent.
159	Xerorthents-Millsholm complex, 30-50% slopes	Moderate permeability; rapid to very rapid runoff	High to very high	Xerorthents consist of soil material resulting from cutting or filling for urban development. The Millsholm series consists of shallow, well drained soils that formed in material weathered from sandstone, mudstone and shale. Millsholm soils are on hills and mountains and have slopes of 5 to 75 percent.
162	Water			

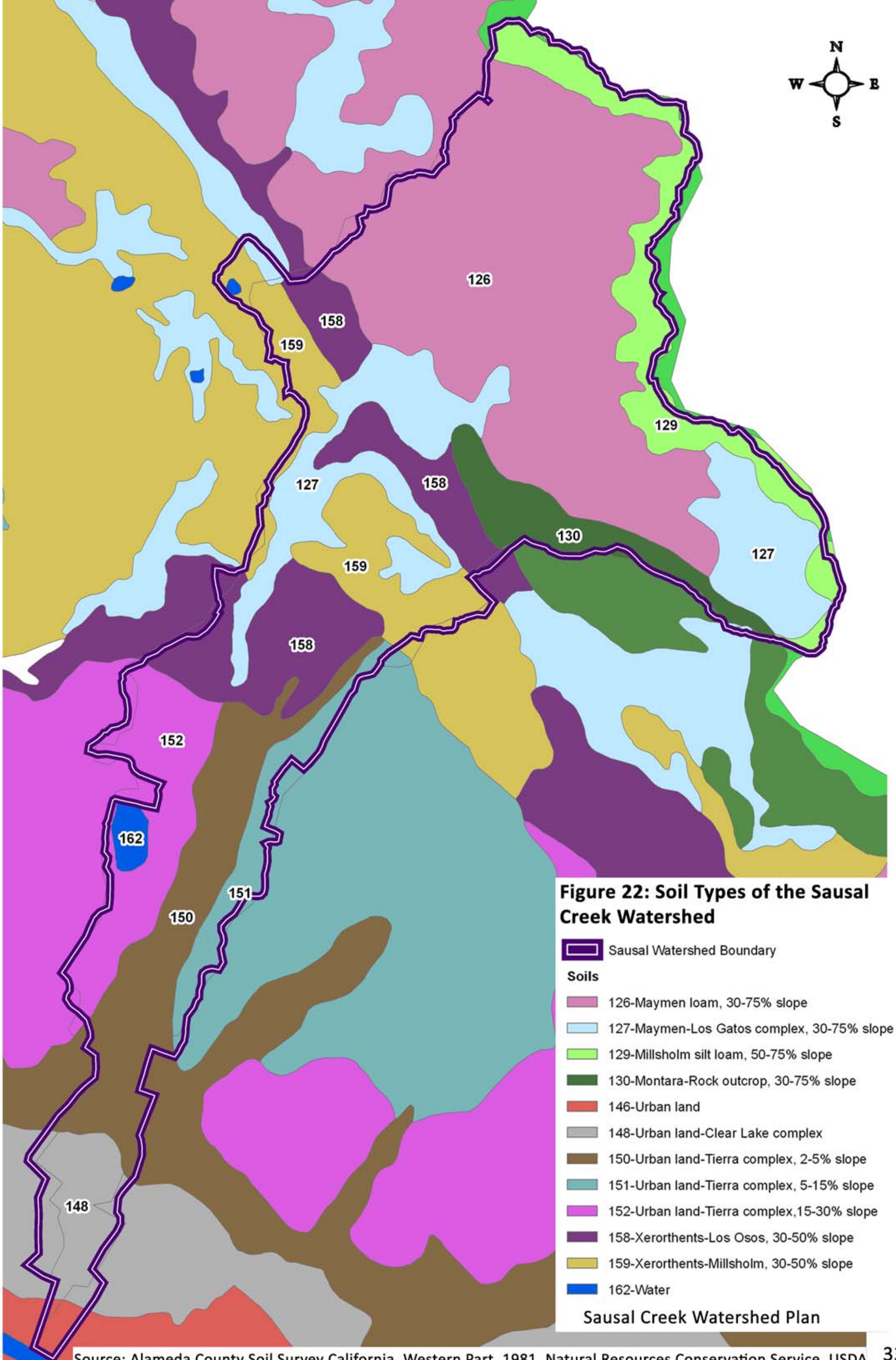


Figure 22: Soil Types of the Sausal Creek Watershed

Source: Alameda County Soil Survey California, Western Part. 1981. Natural Resources Conservation Service, USDA